Effective Waste Management Strategies of Bentonite in Sri Lanka

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ABSTRACT

One of the greatest challenges of Bentonite usage in construction industry is, managing the wastage created in sites thus, it has to be given attention. Therefore, the study would be conducted focusing on the domestic piling construction sites and the process followed by them. Although it is a chemical, it is recognized to be safe for both the environment as well as mankind in an ecological and health protection perspective. However, a proper disposal method in order to reduce the further issues as excessive waste in sites is needed.

Therefore, this study aims to explore an effective method regarding the waste management strategies for Bentonite in Sri Lanka. The objectives of the study are, identifying the wasting methods of Bentonite, identifying causes of disposing Bentonite and determining the most suitable method for Bentonite disposal. Data for the objectives one and two were collected through a literature survey and analyzed by using NVivo which was validated using a questionnaire by majority of 5-10 years experienced professionals aligning to mixed method approach. Data for the third objective was found by aegis of the same questionnaire. Noticeably, it was validated through interviews by the industry experts with more than 30 years of experience.

The study found that, site conditions are the most relatable reason for the Bentonite waste. Apart from that 'weather' and 'manual handling errors' can be additional reasons for the wastage. Moreover, most sites consider either 'when the slurry forms into a cake' or 'silos are full' as the causes for disposal. Furthermore, it has identified that the majority of sites dispose the waste to disposable lands using bowsers as of the disposal method after reusing 3-4 times. The suggested method appears to be cost effective and efficient in comparison to the others. Furthermore, it can be rather safe and environmentally friendly.

KEYWORDS: *Bentonite, Waste Management, Wastage, Sri Lanka, Pile Construction.*

1 INTRODUCTION

Construction is the process of constructing buildings or infrastructure. This particular process differs from manufacturing. (Eve, 2007) In order to complete the procedure, following the Royal Institute of British Architects (RIBA) plan of work is the current practice. This particular plan consists of a brief idea about the process and operation of building projects into eight stages. Further, it gives detailed tasks and output required at each and every stage. Since there were some editions of the RIBA plan, currently it is using the revised plan in 2013. (RIBA, 2021) In order to construct high-rise buildings and large-scale infrastructure projects, the base should be strong. Considering that point the construction industry has an important solution, which is strong enough to bear the weight of those constructions. That is to provide a strong, steady foundation for a structure regardless of soil quantity or harsh environment engineers came up with Piles as a solution (Agyekum, Blay & Opoku, 2019). Pile use in construction is done on unstable soil layers, such as, terminals and refineries which are often located near rivers and gulfs, etc. There are a few pile driving methods as follows: Dropping weight; a hammer with approximately the weight of the pile is raised an appropriate height in a guide and released to strike the pile head. This is a simple method of the hammer in this process. Under this procedure to make the pile stronger, Bentonite clay is used as a hardening material. Bentonite is the chemical substance that is widely used in, current construction. Bentonite is an absorbent clay that concludes with aluminum

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properties formed out of volcanic ash. When liquefied into a slurry, it should be disposed carefully and properly without exposing it to people because there may be security issues. The liquefied Bentonite is used in massive quantities and once all the reusing cycles are done, the bulk of liquid will no longer be in use. Thus, it needs to dispose (Arif, Bendi, Toma-Sabbagh & Sutrisna, 2012). Due to the increase of environmental awareness from utility companies as well as municipal bodies, the intense attention has been focused on drilling fluids and their disposal. That induces challenging conditions on constructions including piling operations. Therefore, the research gap is identified as, the waste management practice in relation to Bentonite in the context of Sri Lanka is not applying in the industry. Hence, it is important to develop new waste management strategies to achieve the proper construction environment (Yean Yng Ling & Song Anh Nguyen, 2013).

Therefore, this study aims to explore an effective method regarding the waste management strategies for Bentonite in Sri Lanka. The objectives of the study are, identifying the wasting methods of Bentonite, identifying causes of disposing Bentonite and determining the most suitable method for Bentonite disposal.

2 LITREATURE REVIEW

Burj Khalifa, Shanghai Tower, Abraj Al-Bait clock tower are some of the tallest towers around the world of which infrastructures facilitate to play a key role in their economies. In line with those developments, the construction industry has obtained an incredible development around the world (Xia, Olanipekun, Chen, Xie & Liu, 2018). With the development, most of the construction projects are large scale projects such as high-rise buildings with underground basements, large-scale infrastructure projects such as underwater tunnels, railways due to its economies of scale (Karunasena, Rathnayake & Senarathne, 2016).

Strong and well-structured sub structure or foundation is a key element to construct large buildings and to provide sound passage to transfer its weight to the subsoil (Lin, Hanna, Sinha & Tirca, 2017). Jarkas has found that, design and scale of foundation depends on various factors such as type of soil, height and weight of the building, and so on (Jarkas, 2010). Especially for high rise buildings and infrastructure projects, modern technology uses Piles (Agyekum, Blay & Opoku, 2019). In modern civil engineering, piles are driven deep into the ground to support super-structure as well as sub-structure. On unstable soils, piles will provide indispensable scaffold to the building and may also be used on stable ground when exceptionally large structural loads are involved (Ahmed, Emira & Tawfik, 2013). Therefore, construction of pile is a key element of construction process, especially those built in locations that are not suitable for freestanding buildings.

There are number of piling types in the construction industry. They are categorized according to various guidelines considering its characteristics such as, mechanism of load transfer, method of installation and type of material (Liyanapathirana, Deeks & Randolph, 2000). Continuity of pile shaft is a mandatory requirement of the successful pile and collapse of pockets of sand into borehole resulting in discontinuity of pile shaft (Adviser, Filtraci, 2012). Bentonite is considered as a highly plastic clay and a widely used commercial application to avoid collapses in to borehole (Chen, Xia, Liu & Wang, 2014).

Past researchers have provided evidence-based prediction of significant increment in global use of Bentonite in the future (Kong, Wang, Ge, Su & Li, 2019). Technological advancements in Bentonite production and increasing demand through exports are identified as major underlying factors anticipated in the growth of Bentonite market in the Asia Pacific Reagan between 2016 to 2025 (Wang et al., 2019).

The construction industry generates a large quantity of waste due to inferior application of waste management systems and inefficient material utilization (Malik, Ahmad, Chen, Altaf & Al-Hussein, 2019). Useless output or the materials and equipment from the construction process is identified as construction waste (Hwang & Bao Yeo, 2011). Therefore, the construction industry has become more interested in moving towards implementing a sustainable construction process to reduce waste and minimal environmental impact during the construction process (Jalaei, Zoghi & Khoshand, 2019). When consider the piling processes, there are several kinds of waste management systems relating to various materials and Bentonite waste management is one of them (Arif, Bendi, Toma-Sabbagh & Sutrisna, 2012).

In the current practice seven causes for waste can be determined which are Design, Workers, Management, Handling, Procurement, Site Conditions, and External factors (Nagapan, Rahman, Asmi, 2012). Under these main causes there are number of wasting types which are commonly observed in construction sites (Rose & Stegemann, 2018). Five major causes of waste and their wasting types are illustrated in the table 1.

Table 1 - Causes of waste

Causes of waste	Reasons of waste
Design	Waste due to inexperience design, lack of design information, poor design quality and design errors, last minute client requirements, frequent design changes
Workers	Lack of awareness, Workers mistakes during the construction, incompetent workers, poor workmanship, and lack of experience
Management	Errors during planning, controlling and supervision, poor in site management, unavailability of effective and efficient equipment
Handling	Wrong material storage, poor material handling, equipment failures, delays during handling
Procurement	Wrong material delivery and purchase, material/items are not compliance with specifications or requirement, use of different methods to estimate, Supply errors and errors occurred during shipping

Source -(Arif, Bendi, Toma-Sabbagh & Sutrisna, 2012), (Nagapan, Rahman & Asmi, 2012), (Alhumoud & Al-Kandari, 2008), (Faniran & Caban, 1998), (Hwang & Bao Yeo, 2011)

In construction industry, waste of materials and equipment is one major problem leading to a reduction of profit. During the piling construction process, there are number of waste items (Arif, Bendi, Toma-Sabbagh & Sutrisna, 2012). Since Bentonite is a material which becomes a waste at the end of pile driving process and there is a process to identify Bentonite as waste material (Faniran & Caban, 1998). Therefore, it is important to develop a new waste management strategy to manage waste of Bentonite to ensure sustainable construction (Yean Yng Ling & Song Anh Nguyen, 2013).

Construction wastage is a subject for many research studies carried out all around the globe, as well in Sri Lanka (Rosado, Vitale, Penteado & Arena, 2019). Commonly, researchers have discussed on wastage of concrete, cement, timber and like, as materials which represent major portion of wastage in construction industry. There is lesser number of studies carried out on the waste of material in the process of pile construction. Thus, this research has been carried out on use of Bentonite clay in process of pile construction, which will be using during the process of pile boring. To focus on Bentonite wasting types and management, a literature survey was done to figure out the general waste types in construction industry, referring to the past literature.

On the other hand, final outcome of successful waste management system is to minimize generation of waste throughout the process. A system's perspective of waste management allows an integrated approach to the five basic functional elements of waste management. That is to say, generation, reduction, collection, recycling, and disposal. Moreover, interfaces with the management of energy, nature conservation, and environmental protection, economic factors like unemployment and productivity are benefitted (Sushil, 2006).

Summary of the survey is shown in below table 2 while the strategies that are commonly used are illustrated in table 3. Table 2 describes various types of wasting methods. Hence, it includes the result of twenty number of various researchers regarding the wasting types in the construction industry.

Table 2 - Types of wastes

Waste types	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20
Wrong material storage	x	x	x			x	x	x		x		x		x	x	x		x	x	
Poor material handling	x	x		x	x		x	x		x					x		x	x		x
Poor quality of materials	x	x		x		x				x				x				x	x	
Equipment failure		x		x		x	x	x			x	x		x			x			x
Tools not suitable used		x			x	x					x				x					
Materials supplied in loose form		x		x					x		x		x			x		x	x	
Inefficient methods of unloading	x	x	x				x				x			x	x	x	x			
Workers' lack of awareness					x			x				x	x		x			x	x	x
Workers' mistakes	x		x						x				x				x			x
Incompetent workers	x				x			x				x	x	x		x		x		
Damage caused by workers		x						x	x		x	x	x				x			x
Inappropriate use of materials	x	x		x		x	x				x		x		x					
Long project duration	x	x			x			x		x		x			x	x	x		x	
Construction methods	x		x		x	x		x	x					x	x		x			x
Poor information quality	x	x		x		x				x		x	x	x		x		x		x
Poor site management	x	x			x		x		x	x	x					x		x	x	x
Poor controlling	x	x	x	x					x	x	x	x	x	x	x		x	x	x	
Poor supervision	x	x	x	x	x	x	x	x		x	x	x		x		x	x		x	
Rework	x			x								x				x	x	x	x	
Wrong material delivery	x	x	x			x					x		x					x		x
Effect of weather			x					x	x								x	x		
Unpredictable local conditions			x	x				x	x						x	x			x	
Ordering errors	x				x	x				x	x	x	x	x						x

A1 -(Nagapan, Rahman & Asmi, 2012), A2 -(Meghani, Vyas & Bhavsar. 2011), A3 - (Kamaruddin, Yusoff & Ahmad, 2015), A4 - (Domingo & Batty, 2021), A5 - (Wu, Zhang & Zhou, 2019), A6 - (Saka, Olaore & Olawumi, 2019), A7 - (Pérez & Costa, 2018), A8 - (Yuan, Shen & Wang, 2011), A9 - (Yates, 2013), A10 -(Yates, 2013), A11 - (Udawatta, Zuo, Chiveralls & Zillante, 2015), A12 - (Udawatta, Zuo, Chiveralls & Zillante, 2015),

A13 - (Park & Tucker, 2016), A14- (Poon, Yu, Wong & Cheung, 2004), A15 - (Hwang & Bao Yeo, 2011), A16 - (Hao, Tam, Yuan & Wang, 2011), A17 - (Rodríguez-Robles, García-González, Juan-Valdés, Morán-del Pozo & Guerra-Romero, 2014), A18 - (Al-Hajj & Hamani, 2011), A19 – (Islam, Raihan, Chowdhury & 2016), A20 – (Muhwezi, Chamuriho & Lema, 2012)

Table 3 - Waste management strategies

Strategy	Explanation
Prevention	Prevention is the best method in waste management. Giving attention to the technical information about construction process helps in preventing construction waste.
Minimization	Minimizing is the second most preferred method. Reducing the waste generating factors from the beginning helps in reducing the ultimate amount of waste.
Reuse	Thirdly, reusing before the disposal is known to be an effective way as well.
Recycle	Recycling comes fourth factor that helps in waste management.
Recovery	'Recovery' helps in removing materials or components and making it reusable.
Disposal	Disposal is the last option it is mostly used among construction sites in many countries

Including Piling, construction processes use Bentonite, either for horizontal drilling or slurry wall construction. After Bentonite slurry utilized or labeled as “spent”, there is a need for disposal because the remaining beneficial properties at the completion of pile driving process has not been identified (Lawson, Douglas & Garvin, 2011). Therefore, it has been a major concern of identifying the existence of beneficial properties after the use of Bentonite (Chatziaras, Psomopoulos & Themelis, 2016).

In most scenarios, it tends to dispose Bentonite after few cycles. Whilst few other construction companies tend to follow some in-site tests to check the properties which appears to be effective. Depending on the results and comparing them with the specification, it is decided to dispose or to keep continue.

Another major issue is inconsistent use of Bentonite. Moreover, storing for days would result in settling and caking if not agitated (De Silva and Vithana, 2008). In addition, the very property of swelling in water upon which are useful applications of Bentonite lead to serious problems in the handling, delivery, and transportation of Bentonite clays (Hwang & Bao Yeo, 2011).

3 AIMS AND OBJECTIVES

In considering the background study of the case, research question is what the effective uses and waste management strategies of Bentonite in Sri Lanka are. To figure out the answer for this question, the research aims ‘To identify the effective uses and waste management strategies of Bentonite in Sri Lanka’.

In fulfilling the aim, research had been carried out to achieve three main objectives. First and foremost, it is needed to identify the causes of Bentonite waste. Second objective is identifying the causes for disposal of Bentonite. That is to say, the reasons for the disposal should be known. Thirdly, identifying the most suitable disposal method for Bentonite in Sri Lanka should be identified.

4 RESEARCH METHODOLOGY

Any research needs the related data which are in either qualitative form or quantitative form. To collect essential data that appears in both types, this research has used the ‘mixed-method’ which consisting of both the data.

As a primary stage, background study has been carried out based on past studies amalgamating with “NVivo 12”. Literature review has been carried out with the aid of books and past research articles those are in line with the subject matter. In second phase, a questionnaire has been drafted based on past studies. Thereafter, a pilot test has been conducted with the support of industry experts to check the effectiveness of the draft questionnaire. Then the questionnaire has been finalized accordingly.

Following that, the questionnaire had been circulated among 30 no of industry professionals. Collected data had been verified by using face to face interviews with 10 no of senior professionals of the industry.

5 DATA COLLECTION AND ANALYSIS

In the first section of the questionnaire, demographical data of the participants were analyzed. In order to do so, the profession, age, educational background and experience in related aspects were given attention. Mostly, engineers, quantity surveyors, project managers and construction workers from the age groups between 21-50+ have responded to the questionnaire. Both aspects of educational background and experience in this particular area has varied among the responders. Evidently, the duration of experience too has varied resulting in different point of views relating to the subject matter. Especially, experience in construction industry and piling were given attention.

Table 4-Position at Company

Position	No of responds
Engineer	13
Quantity Surveyor	5
Consultant	4
Project Manager	4
Other	3
T.O.	1
Architects	0

Table 5- Experience in Construction Industry

Experience in Construction Industry	No of responds
1-5	18
6-10	7
11-15	1
16-20	2
21-30	2
31-40	0
41-50	0
51+	0

Table 6- Experience in piling

Experience in Piling	No of Responds
1-5	27
6-10	0
11-15	2
16-20	1
Above 20	0

Out of the 30 responders, 13 of them are engineers whereas 5 are QS, 4 responds were coming from both categories of PM and consultants. Most of the responders are from the age groups of 21-25 and 31-35 mostly with experience in construction industry from 1-5 years. 27 responders claimed to have 1-5 years of experience in ‘piling’ while only two people had it for 11-15 years. On the other hand, 40% of the responders are bachelor’s degree holders whereas less people have other educational qualifications such as PhDs. During the research, the responses given by these respondents with both professional and educational background who are experienced in the construction industry were analyzed. Thus, the concluded data analysis contains the ultimate result found within the responses.

Afterwards the contextual data has been analyzed in terms of qualitative and quantitative forms which directly affect the main objectives of the research. First concern has been whether the responders have experience in using Bentonite.

Table 7- Bentonite usage

Usage	No of Responds
High	11
Moderate	14
Less	3

Table 8- Number of cycles

Number of Cycles	No of Responds
1-2 Cycles	10
3-4 Cycles	17
5-6 Cycles	3
More than 6	0

It can be concluded that majority has a moderate experience in using Bentonite. Along with that, the number of reuses was concerned thus found that most sites go with 3-4 cycles of reusing. It was also found that additional chemicals are not mixed with Bentonite slurry in most instances but rarely cement and pipe-clay are used as additional chemicals or materials.

Table 9- Bentonite Wastage

Wastage	No of Responds
High	4
Moderate	14
Less	12

In the questionnaire it was also asked the responder's opinion on Bentonite wastage which appears to be a moderate wastage according to most of them. While most of the QSs found it to be 'less', engineers, PMs and consultants found it to be on a 'moderate' scale.

Table 10- Reasons for Bentonite waste

Type of Cause of Waste	No of Responds				
	Least	Less	Moderate	More	Most
Calculation Errors	5	7	3	0	0
Manual Handling Errors	1	6	12	4	1
Site Conditions	0	1	6	16	3
Weather	1	4	9	10	1
Wrong Material Storage	5	3	4	0	0
Poor Quality of Materials	4	3	5	0	0
Long Project Duration	4	6	6	1	0
Management Errors	4	6	1	1	0

When the reasons are concerned, site condition appears to be the major reason for Bentonite wastage according to the opinion of most of the experienced people in this matter. That is to say, 24 out if the 30 respondents have agreed on this. Moreover, 'weather' and 'manual handling errors' are some other major reasons according to the opinions of the responders which is 21 and 16 respectively. If consider the severity of reasons, it shows that site condition affects the wastage the most while manual handling errors affect moderately. Similarly, 'poor quality of materials' and 'long project duration' has a moderate effect on this matter. While calculation errors effects lesser wrong material storage has the least effect on Bentonite wastage.
The below set of tables indicate the figures which were analysed by the data collected in relation to the process of disposal.

Table 11- Time of disposing

Time of Disposing	No of Responds
When silos are full	18
When slurry is forming to a cake	17
When the system is malfunctioning disposing factor	10
When too old.	17

Table 12- Severity of disposing factor

Type of Disposing factor	No of Responds				
	Least	Less	Moderate	More	Most
When silos are full	2	6	5	6	4
When slurry is forming to a cake	0	0	5	9	5
When the system is malfunctioning disposing factor	3	5	7	3	0
When too old.	3	2	5	8	4

Table 13- Procedure of disposing.

Procedure of Disposing	No of Responds
Dispose by bowser to disposable lands	24
Direct disposal into sewer canal	6

Process of disposal also was given attention in the questionnaire. Evidently the disposal is done only after reusing the Bentonite mixture. According to the research, the disposal of the slurry is decided when the silos are full. Severity factors are mostly when the slurry forms a cake or if it is too old. When it comes to the disposal methods only two are recognized thus it is done either by disposing to a disposable land by a bowser or directly disposing into sewer canals. Moreover, opinions regarding Bentonite wastage were collected from each individual which is based on their profession and experience on this subject area.

According to the analysis 80% of participants identified, site conditions are the most relatable reason for Bentonite wastage. Position wise majority of this 80% was Engineers, second and third highest are respectively Quantity Surveyors and Consultants, and they belong to age category of 31-35 years mostly with 1-5 years of experience in pile construction.

Under second objective, most of the participants, as s number 60% selected when silos are full as the reason for disposing Bentonite. Majority of them are Engineers with 1-5 years of experience in pile construction and age category of 26-30 years.

According to the responses of the participants for the question which is the currently using disposing procedure large count of them identified the method of disposing by bowser to disposable lands. As a figure it is 80%.

Participants were asked to suggest the most suitable disposing method for Bentonite according to their point of view. Participants were come up with a few ideas and for reasons for it.

Table 14- Summary of suggested disposal method

Dispose with bowser into disposable lands	60%
Dispose of sewer canals/ lines	16%
Form into polynomial compounds and recycle	20%

As per the above summary table most of the participants are suggested disposing using a bowser into disposal lands as the most suitable disposing method for Bentonite. As a percentage, it is about 60%. As well as participants are suggested form into polynomial compounds and recycle in second place and dispose of sewer canals/ lines in the third place.

Table 15- Summary of reasons for suggested method

Environmentally friendly and less pollution	40%
Cost effective & Time management	43%
Easy to handle	17%

Participants of this study have come up with the above suggestions due to various reasons such as efficiency, cost-effective, time management and environmental reasons, since Bentonite is not very much environmentally friendly. It may occur cautions if it mixes up with groundwater as well as drinking water. The summary of the reason is in the above given table.

6 CONLUSION

This study focusses on exploring an effective methods for waste management strategies of Bentonite in Sri Lanka, under three specific objectives. Data was collected and analyzed using the mixed method.

The first objective of the research was to identify the Bentonite wasting methods. Albeit the several ways the Bentonite are being wasted, responders have suggested that ‘site condition' is the major reason when it comes to Bentonite wastage. Methods such as calculation errors, management errors and long duration of a project has a lesser impact on the Bentonite wastage.

The second objective has been identifying causes for disposal of Bentonite. It was recognized disposal is most appropriate when the silos are full. However, there is also a possibility of it being disposed due to the slurry turning to a cake or being old.

The third objective was to identify the most suitable disposal method for Bentonite in Sri Lanka. It was suggested that since Bentonite is not eco-friendly, disposal by bowser to a disposable land would be a safer option rather than disposing into sewer canals. Moreover, a less number has suggested a third option that is considered to be cost-effective.

7 RECOMMONDATIONS, LIMITATIONS AND WAY FORWARD

On a final remark, among many reasons for the Bentonite to be wasted site condition can be recognized as the major reason. The research targeted in finding out a strategy that would be effective in managing Bentonite wastage in Sri Lanka. Considering the fact that site condition is the major reason for increasing the wastage amount the research suggests that sites should be more considerate on the condition of it. Moreover, working on the improvement of site condition and managing it in a proper manner can be a help in both minimalizing Bentonite wastage as well as cost control. In the disposal procedure, it is suggested that using a bowser to transport disposing Bentonite to be effective. In addition

to that reuse and recycle can be seen as alternatives that help in improving the waste management of Bentonite.

Furthermore, limitations figured out of this research are as follow; most of the experts as well as workers are slightly less experienced on pile construction and the construction sites considered to collect data was in middle range and the leftover of Bentonite was minimal. Hence, applying the waste management strategies are somewhat difficult due to the point. Other than that, the research was conducted within six months of period.

In addition, this research can be done in more effective way considering the large-scale pile construction sites.

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